

SGTT
SPM Synaptic Gains Tracking Toolbox
Manual

1. INTRODUCTION

SGTT, a SPM EEG synaptic gains tracking toolbox, allows to

1. track the average excitatory A_e , slow and fast inhibitory synaptic gains, B and G , by automatically fitting EEG data to a neural mass model;
2. compute four synaptic gain ratios (excitatory/slow inhibitory A_e/B , excitatory/fast inhibitory A_e/G , excitatory/(slow + fast) inhibitory $A_e/(B+G)$, and slow/fast inhibitory ratio B/G , and smooth them using moving average filter;
3. display the path to epilepsy through the synaptic gain space.

The method is described in [Fan2018a] and [Fan2018b].

The synaptic gains were estimated in four steps:

1. Pre-processing. The EEG first go through a bandpass filter and notch filter after zero-score normalization.
2. The EEG is segmented into fixed-size windows.
3. Search the synaptic gain space exhaustively and find the top N (defined by the user) fits as candidates.
4. Cluster the candidates and compute the means of the cluster with the smallest average error as the most representative fit.

This manual gives you a guideline to use the EEG synaptic gains tracking toolbox (version 1) which was implemented in SPM version 12 (SPM12) [Ashburner2013]. This algorithm is detailed in [Fan2018a] and [Fan2018b]. We highly recommend you to install the EEGAnalyzer toolbox (<https://bitbucket.org/ulbeeg/eeganalyzer>), which is also a toolbox (version 1) for SPM 12, for a better visualization.

Matlab R2013a was used for the development of this toolbox. Please also refer to the SPM user manual [Ashburner2013].

If you use this toolbox for a publication (in a journal, in a conference, etc.), please cite it by including as much information as possible from the following:

Xiaoya Fan, Rudy Ercek, Antoine Nonclercq. SGTT: a SPM EEG Synaptic gain tracking toolbox, Université Libre de Bruxelles, <http://beams.ulb.ac.be/research-projects/synaptic-gains-tracking-toolbox>

Fan, X., Gaspard, N., Legros, B., Lucchetti, F., Ercek, R. & Nonclercq, A. (2018). Dynamics underlying interictal to ictal transition in temporal lobe epilepsy: insights from a neural mass model. *European Journal of Neuroscience*, 47(3), 258-268. doi: 10.1111/ejn.13812

Fan, X., Gaspard, N., Legros, B., Lucchetti, F., Ercek, R. & Nonclercq, A. (2018). Seizure evolution can be characterized as path through synaptic gain space of a neural mass model. *European Journal of Neuroscience*, doi: 10.1111/ejn.14142.

2. LICENSE

As SPM, the license attached to this toolbox is GPL v2, see <https://www.gnu.org/licenses/gpl-2.0.txt>. From <https://www.gnu.org/licenses/gpl-2.0.html>, it implies:

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3. SPM AND SGTT INSTALLATION

- 1) Download SPM12 Toolbox on the website : <http://www.fil.ion.ucl.ac.uk/spm/>
- 2) Decompress the SPM12 zip file (spm12.zip) in a folder of your choice.
- 3) Run Matlab and add the SPM folder to Matlab search path: Menu “HOME” and button “Set Path” in the last Matlab versions. Another solution: go to the SPM folder and type the command “addpath(pwd)” each time you want to run SPM in Matlab.
- 4) Download the SGTT toolbox on the website:
<http://beams.ulb.ac.be/research-projects/synaptic-gains-tracking-toolbox>
- 5) Decompress the zip file in toolbox folder under the SPM folder. The “SGTT” folder should be present in the “toolbox” folder under the SPM folder.
- 6) Download the EEGAnalyzer toolbox on the website:
<https://bitbucket.org/ulbeeg/eegalyzer>
- 7) Decompress the zip file in “toolbox” folder under the SPM folder and rename the decompressed folder to “EEGAnalyzer” (case sensitive).

4. CONVERSION FROM EDF (OR OTHER EEG) FILE TO SPM FILE

- 1) Set the working path to the SPM folder and Run SPM by typing the “spm” command in Matlab; SPM main window with 6 buttons appears (Figure 1).
- 2) Click on the “M/EEG” button (1) in Figure 1; three windows (figures) appear, among which the “Menu” window shown in Figure 2.
- 3) In the list box “Convert” (1) of the Menu window (Figure 2), select and click “Convert” (scroll this window to select it!); the “Select M/EEG data file” window (Figure 3) appears.
- 4) In this window, select the EEG file you want to convert and click on “Done” (1). The file “EEG sample.edf” is selected for illustration. Another window with “M/EEG data conversion” appears (Figure 4).
- 5) This window (Figure 4) asks the user to “Define Settings”. You should answer “Yes” (1) (the “Just Read” button (2) could also work depending on your case).

- 6) The “Batch Editor” window for “Conversion” module now appears (see Figure 5). It presents several options. If the EEG file is too large (e.g. EEG channels cannot be easily displayed, display is slow, Matlab crashes when trying to display EEG channels), change “Reading mode” “Continuous” (1) from “Read all” (2) to “Time Window” in order to take only an epoch of interest from the signal (e.g. from 3000 to 4000 sec). These options can also be used with another module called “Crop” in the “Preprocess” window Menu (scroll (2) in Figure 2). You can choose selective channels by modifying the channel selection (3) from “All” to e.g. “Custom Channel” and specify the channel(s) of interest. By default, a prefix “spmeeeg_” is added to the original filename after conversion. You can change the output filename by “Output filename” option (4). Figure 6 presents the “Batch Editor” with some of these options modified. If one option is selected, (8) in Figure 6 shows the help information of this option and the option can be changed in (6) in Figure 6 by either selecting among several options provided by default or click “specify” i.e. (7) in Figure 6 , to enter proper value(s).
- 7) After configuring the options of the “Batch Editor”, you can start the conversion by clicking on the “play” button (5) of Figure 5 (green triangle). A SPM EEG file is created in the current Matlab directory (the current Matlab directory has to be writable!); a SPM file is composed of two files: a matlab file (.mat) containing the header information and a data file (.dat) containing the EEG samples.

Please refer to the SPM manual for further information about converting EEG files [Ashburner2013].

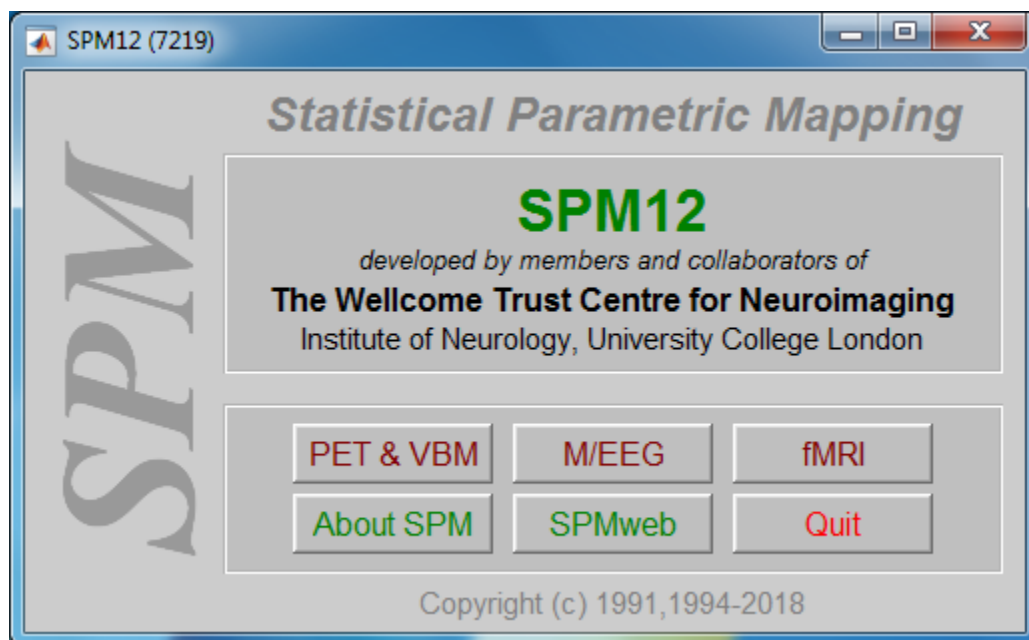


Figure 1. SPM main window

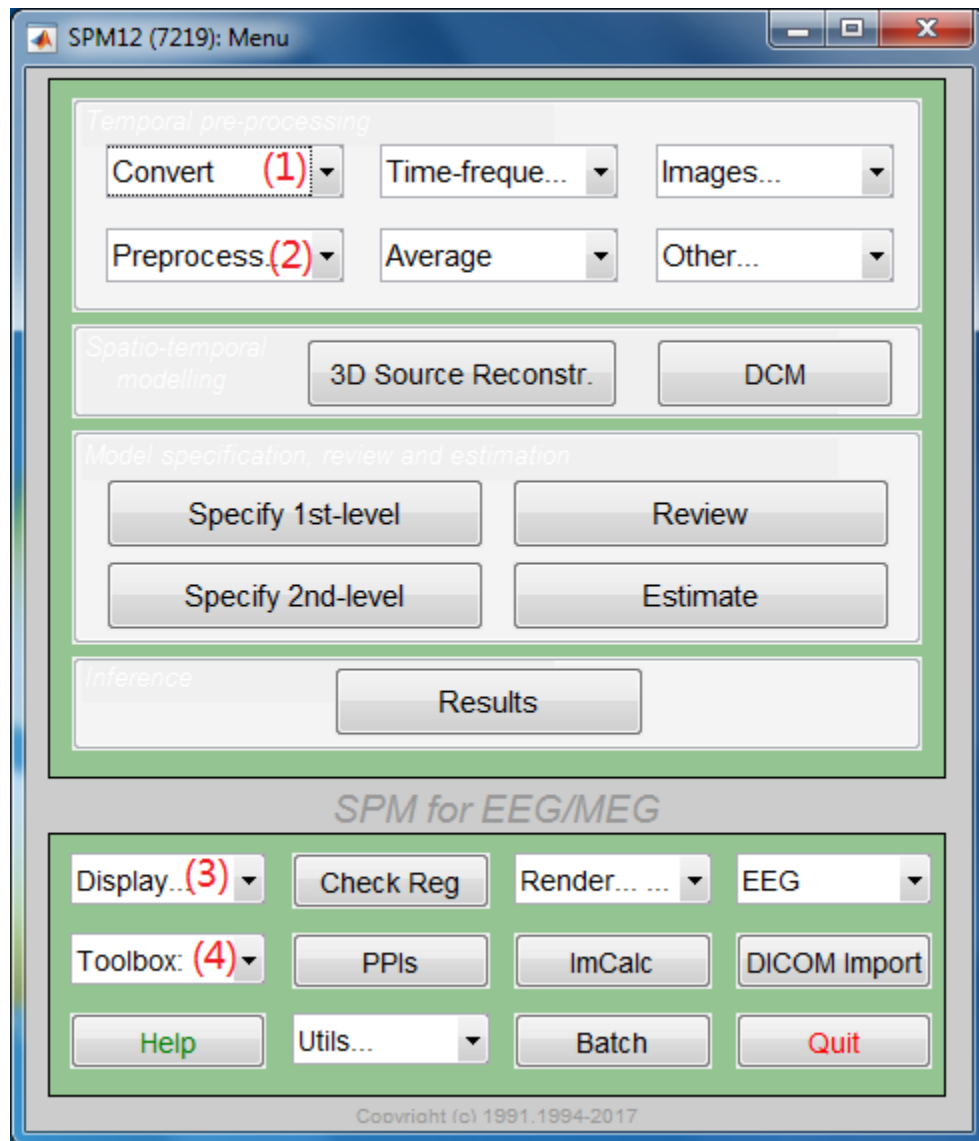


Figure 2 SPM Menu

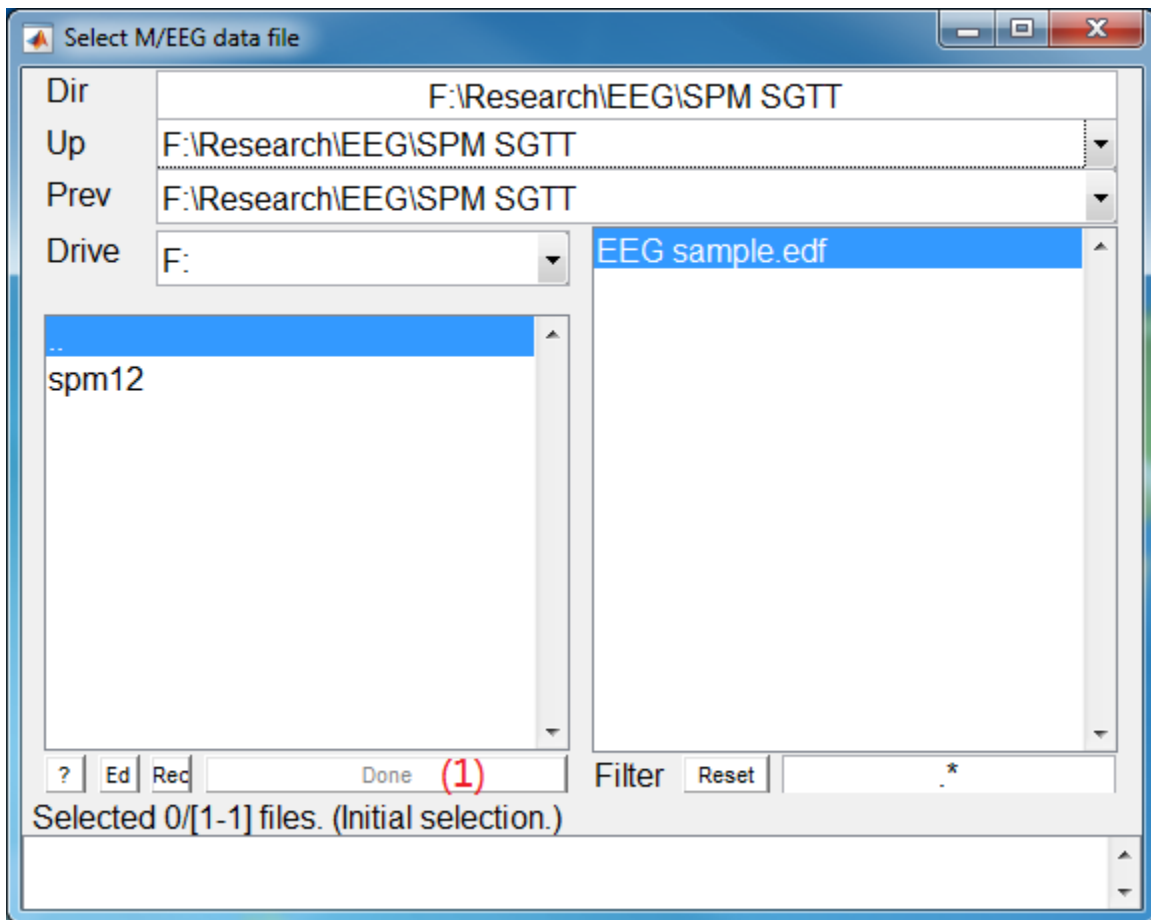


Figure 3. Select M/EEG data file window for file conversion

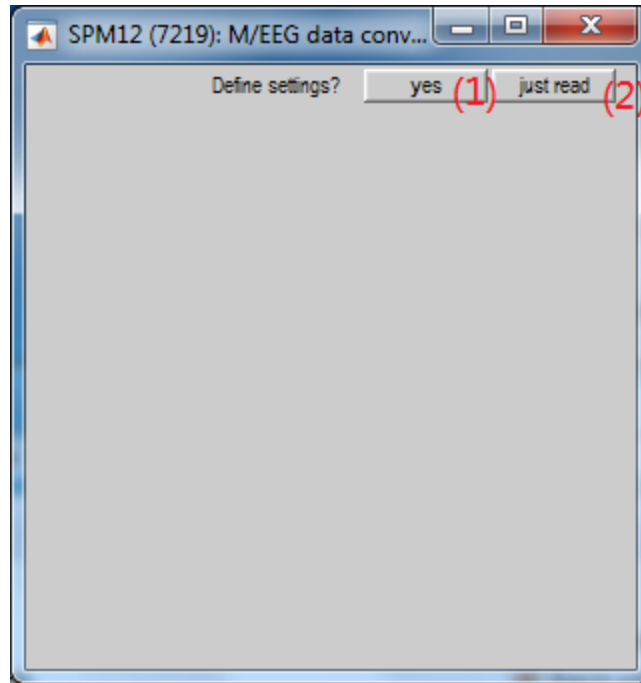


Figure 4. M/EEG data conversion window in order to "Define Settings"

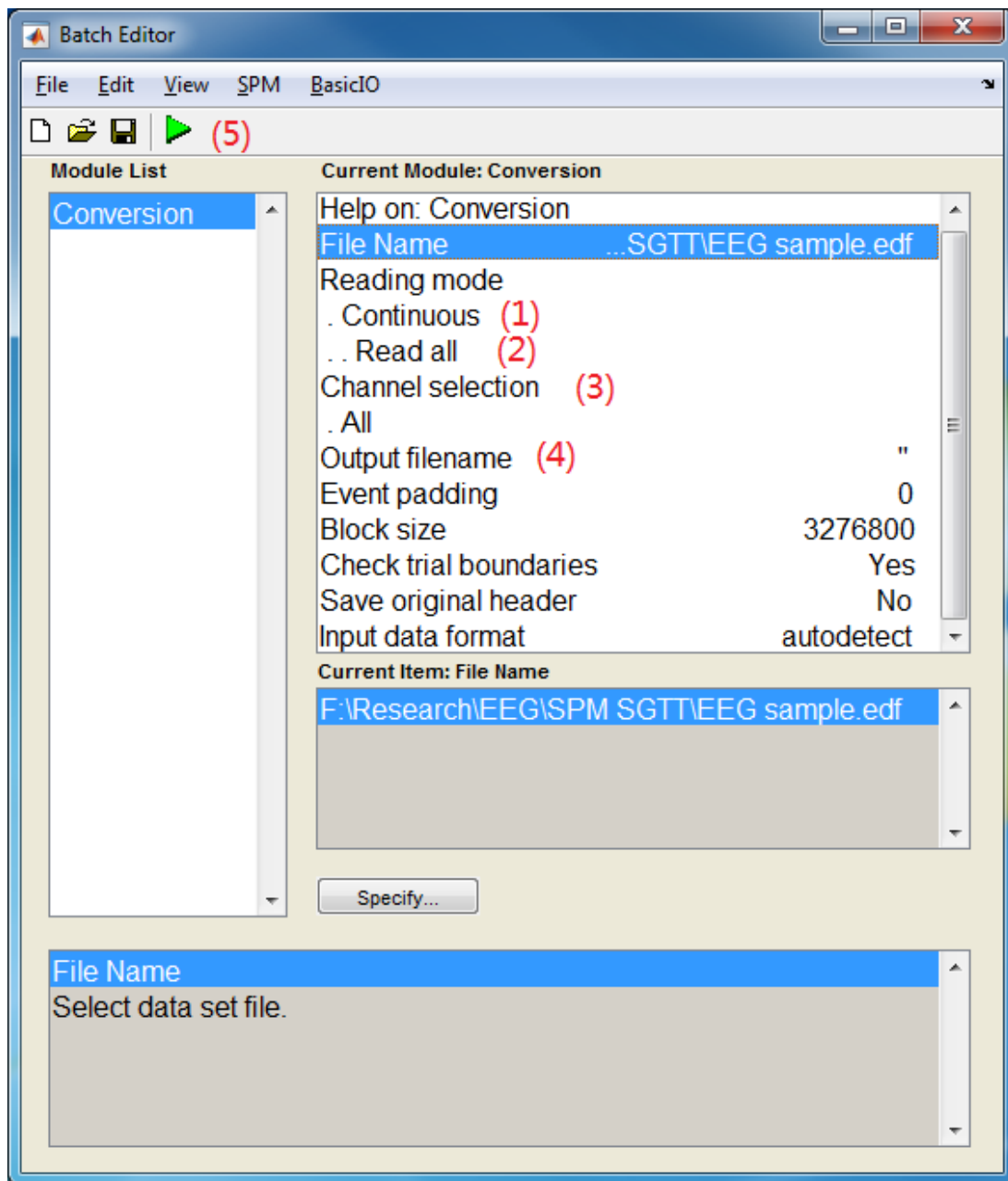


Figure 5. Batch Editor for EEG file conversion with default options

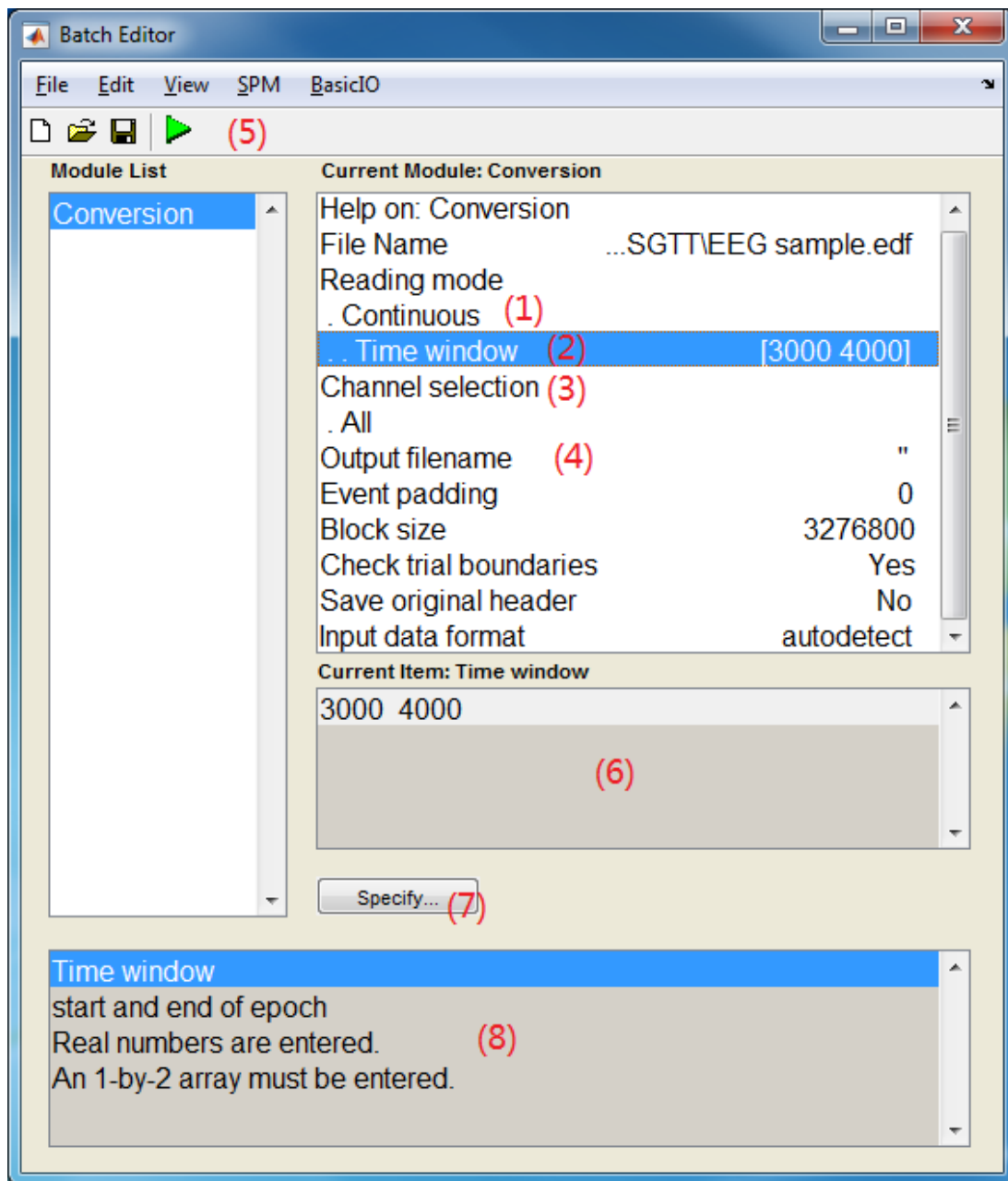


Figure 6. Batch Editor for EEG file conversion with options changed

5. DISPLAY THE SPM (EEG) FILE

A SPM EEG file can be displayed in the “Graphics” window shown in Figure 7. To do so, you have to select the “M/EEG” option in the “Display ...” list box (3) of the SPM menu (see Figure 2). Figure 3 will disappear and you can select the SPM header file (.mat file after conversion, with prefix “spmeeg_” if default output filename is used) you want to display and then click “done”. If channel types are automatically recognized after conversion, channels are often plotted in the tab “EEG” (1) of the “Graphic” window. Sometimes the channel types are not recognized, if so, channels are often plotted in the tab “OTHER” (2) of the “Graphic” window.

Another interesting tab is the “info” tab (3) where you can have some information about the EEG file. Several buttons can be used in the “Graphics” window to change the plot configuration (e.g. for time (6) and (7), and voltage amplitude (8) and (9)). Please refer to the SPM user manual for more information about these controls [Ashburner2013].

Let us notice that, in most cases, the tabs “MEG”, “MPLANAR” and “MCOMB” of the “Graphics” window are empty. The tab “EEG” gives the plot of EEG channels in the SPM EEG file.

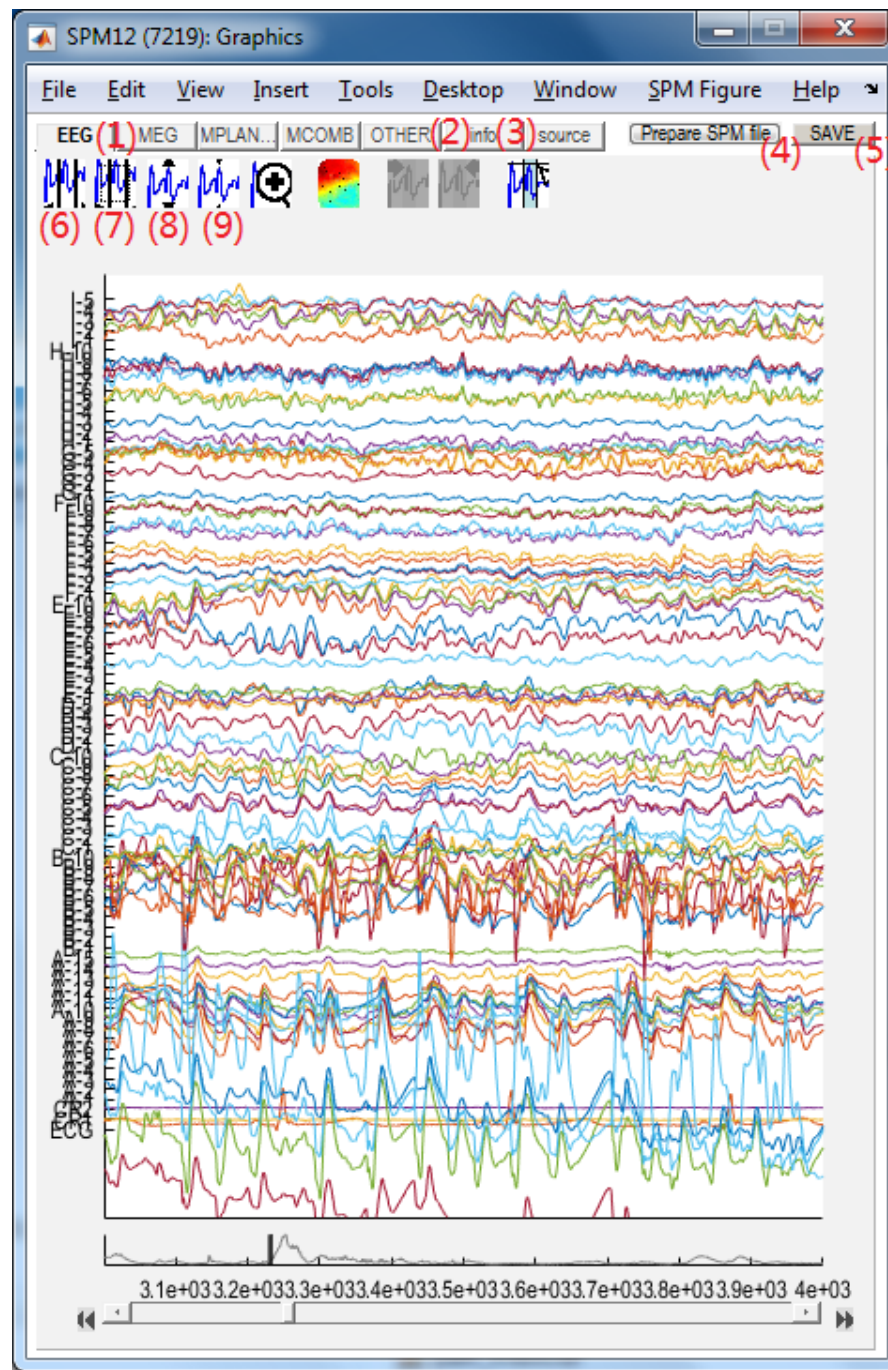


Figure 7. Display of a SPM EEG file in the "Graphics" window

6. SYNAPTIC GAIN TRACKING TOOLBOX

This section will mainly focus on explaining how to use this toolbox.

GUIDELINE

The use of SGTT is quite straightforward:

After the conversion is done, scroll the window “Toolbox:” (4) in the SPM Menu (Figure 2) and select SGTT. Then a window appears, different options are provided for you to choose (Figure 8).

- Compute average synaptic gains (Ae, B and G)
 - 1) Select the first option “Compute Neuro Mass Model Parameters (Ae, B, G)” (1), then Figure 3 appears and select the SPM file you want to analyze (the .mat file after conversion, with prefix “spmeeeg_” if default output filename is used).
 - 2) A “Select channels” window appears and select the channel(s) you want to analyze (we select channel A-1 and B-1 in this example).
 - 3) After selection of channels, a window pops up and you can specify ad hoc parameters for estimating the average synaptic gains (Figure 9). They are:
 - a. “Window width (s)”: Window size of the sliding window, within which the average synaptic gains are estimated. By default it is set to 2s.
 - b. “Window step (s)”: Window step of the sliding window. By default it is set to 0.1s.
 - c. “Candidate number (in [1, 1000])”: The number of pre-selected candidate solutions. By default it is set to 50. These candidate solutions (triplets) will be clustered to determine the most representative fit of the EEG segment.
 - d. “Low pass filter cut off (Hz)”: For preprocessing the EEG signal. By default, it is set to 64Hz.
 - e. “High pass filter cut off (Hz)”: for preprocessing the EEG signal. By default, it is set to 0.16Hz.
 - f. “Notch filter”: For designing notch filter to remove the powerline interference, choose between 50Hz and 60Hz.
 - g. “Output filename”: This step outputs a SPM file. The filename adds a prefix “AeBG” by default. You can specify the output filename by yourself. The file is saved in the current Matlab folder.

For details about the ad hoc parameters, please see [Fan2018a] and [Fan2018b].

After all ad hoc parameters are specified, the computation starts. Let us note that the type of average synaptic gains (excitatory Ae, slow and fast inhibitory B and G) was not specified. This means that when display it using the “Display” module of SPM (detailed above in the previous section “DISPLAY THE SPM (EEG) FILE”), Ae, B and G will be displayed under the “OTHER” tab, i.e. (2) in Figure 7. The channel names are Ae, B or G with prefix of corresponding EEG channel name, i.e. “A-1_Ae”, “A-1_B” and “A-1_G” for synaptic gains computed from EEG channel “A-1”.

- Compute cues: after the average synaptic gains are computed, it is interesting to compute the cues for investigating the excitatory/inhibitory synaptic gain ratios.
 - 1) Select “Compute cues”, i.e. (2) in Figure 8, if you are interested in the synaptic gain ratios. Again Figure 3 appears and select the SPM file you want to analyze (the .mat file after the previous step, with prefix “AeBG” if default output filename is used), then select the channel(s) you would like to analyze and the cues you would like to compute (Figure 10). Let us note that the Ae, B and G can also be selected in this step. If selected, relative options will be asked for you to specify (see below). The smooth cue $Ae/(B+G)$, smooth cue Ae/G , smooth cue Ae/B are the most interesting, since they allow to analyze the global trend of excitatory/inhibitory synaptic gain ratios. The parameters Ae, B, G and the smoothed ratios were chosen in the following example.
 - 2) Then Figure 11 appears for specifying ad hoc parameters for computing cues. They are:
 - a. “Filter window size for cues (s)”: The window size for moving average filter for smoothing the cues. By default it is set to 30s.
 - b. “Ae, B & G Amplification” (only appears when “parameters Ae, B, G” is selected): The coefficient to amplify Ae, B and G. We amplify the synaptic gain for better visualization in the SPM Graphics window. By default it is set to 10.
 - c. “Filter window size for Ae, B, G (s)” (only appears when “parameters Ae, B, G” is selected): The window size for moving average filter for smoothing Ae, B, G. By default it is set to 0s, which means no smooth.
 - d. “Cues Amplification”: The coefficient to amplify the cues (Ae/G , Ae/B , $Ae/(B+G)$ and B/G) and the smoothed cues. This is for better visualization. By default, it is set to 1000.
 - e. “Output filename”: The output is a SPM file. The filename adds a prefix “Cues” by default. You can specify the output filename by yourself.

Default values are chosen in the following example except that “Filter window size for Ae, B, G (s)” was set to 30s. After all ad hoc parameters are specified, the computation starts. Let us note that the type of cues was not specified. This means that when display it using the Display module of SPM (detailed above in DISPLAY THE SPM (EEG) FILE), the cues will be displayed under the “OTHER” tab, i.e. (2) in Figure 7. The labels are (a or s)Ae, (a or s)B, (a or s)G, (s)R1, (s)R2, (s)R3, (s)R4 with prefix of corresponding EEG channel name, i.e. “A-1aAe”, “A-1sAe”, “A-1_R1”, “A-1sR1” represent raw Ae (indicate by letter “a” before Ae), smoothed Ae (indicate by letter “s” before Ae), $Ae/(B+G)$ and smoothed $Ae/(B+G)$ computed from EEG channel “A-1”, (s)R1 to (s)R4 represent (smoothed) $Ae/(B+G)$, Ae/G , Ae/B and B/G , respectively.

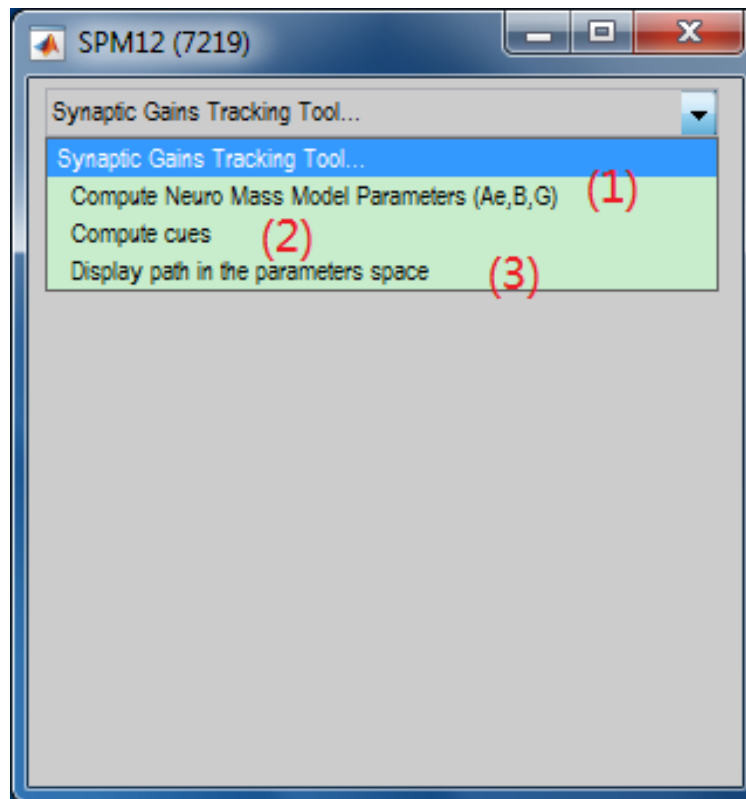


Figure 8. SGTT window

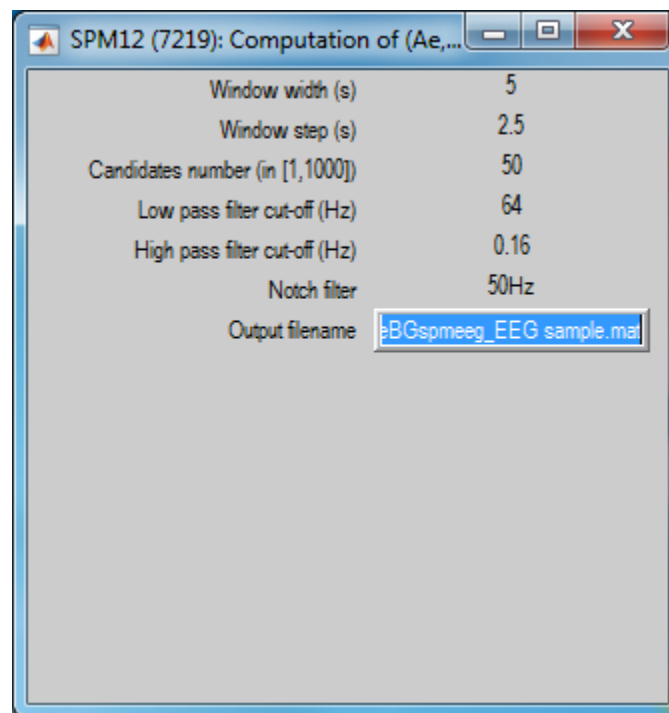


Figure 9. Specify the ad hoc parameters for estimating the average synaptic gains

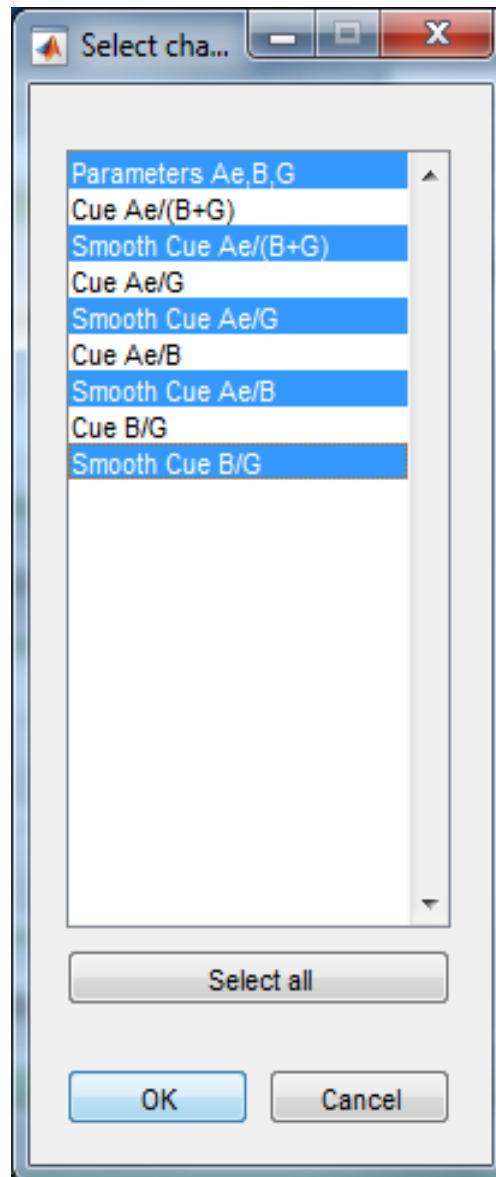


Figure 10. Select cues

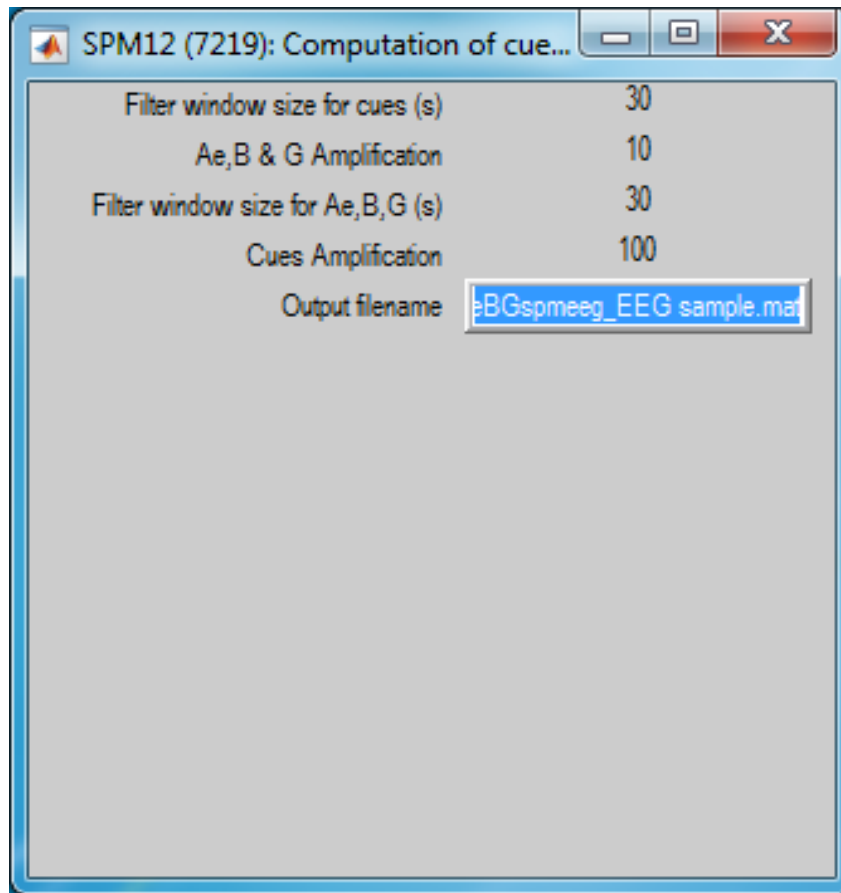


Figure 11. Specifying ad hoc parameters for computing cues

- Display path to epilepsy:
 - 1) Select “Display path in the parameters space”, i.e. (3) in Figure 8 if you are interested in the path to epilepsy through the parameter space (3D). Again Figure 3 appears and select the SPM file you want to analyze (the .mat file after the computing Ae, B and G, with prefix “AeBG” if default output filename is used), then select the channel(s) you would like to analyze.
 - 2) Figure 12 appears for specifying ad hoc parameters for displaying the path. They are:
 - a. “Filter window size”: The window size for moving average filter for smoothing the average synaptic gains. By default it is set to 10s.
 - b. “Path start (ms)”: The start time of the path. Use together with “Path stop (ms)”. By default it equal to: start of the epoch under study + Filter window size for cues.
 - c. “Path stop (ms)”: The stop time of the path. Use together with “Path start (ms)”. By default it is equal to: end of the epoch under study - Filter window size for cues.

It is particularly useful to specify the starting and ending time of the path if the recording is very long. It is of great interest to investigate the temporal evolution of synaptic gains before, during and at the termination of a seizure. To do this, the path should include a seizure. In the future release, a module for detecting seizures based on the synaptic gain ratios will be included. Figure 12 shows the parameter set in the given example.

After all ad hoc parameters are specified, the computation starts. After computation, two windows pop up (Figure 13 and Figure 14). Figure 13 shows the path in the 3D parameter space Ae, B and G) calculated from the epoch specified by “Path start (ms)” and “Path stop (ms)”. Figure 14 shows the same path, but projected to 3 different views. The path starts in red and ends in blue. It shows the temporal evolution of synaptic gains and reflects the interaction among the 3 neuronal populations (excitatory, slow and fast inhibitory).

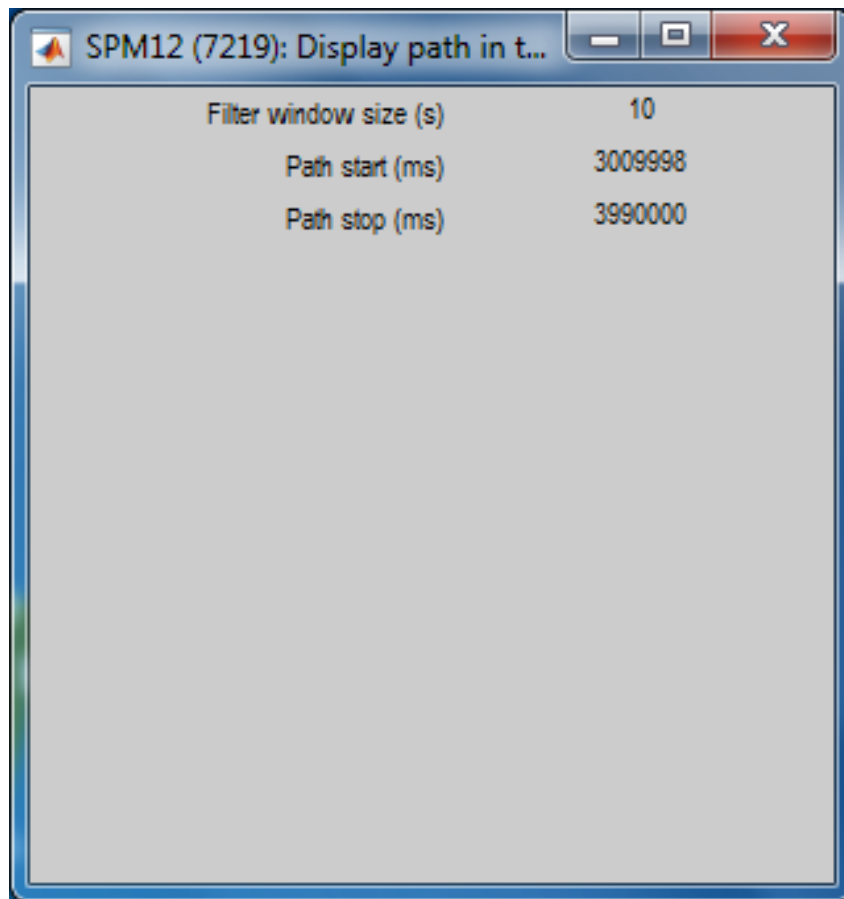


Figure 12. Specifying ad hoc parameters for displaying the path in the parameter space.

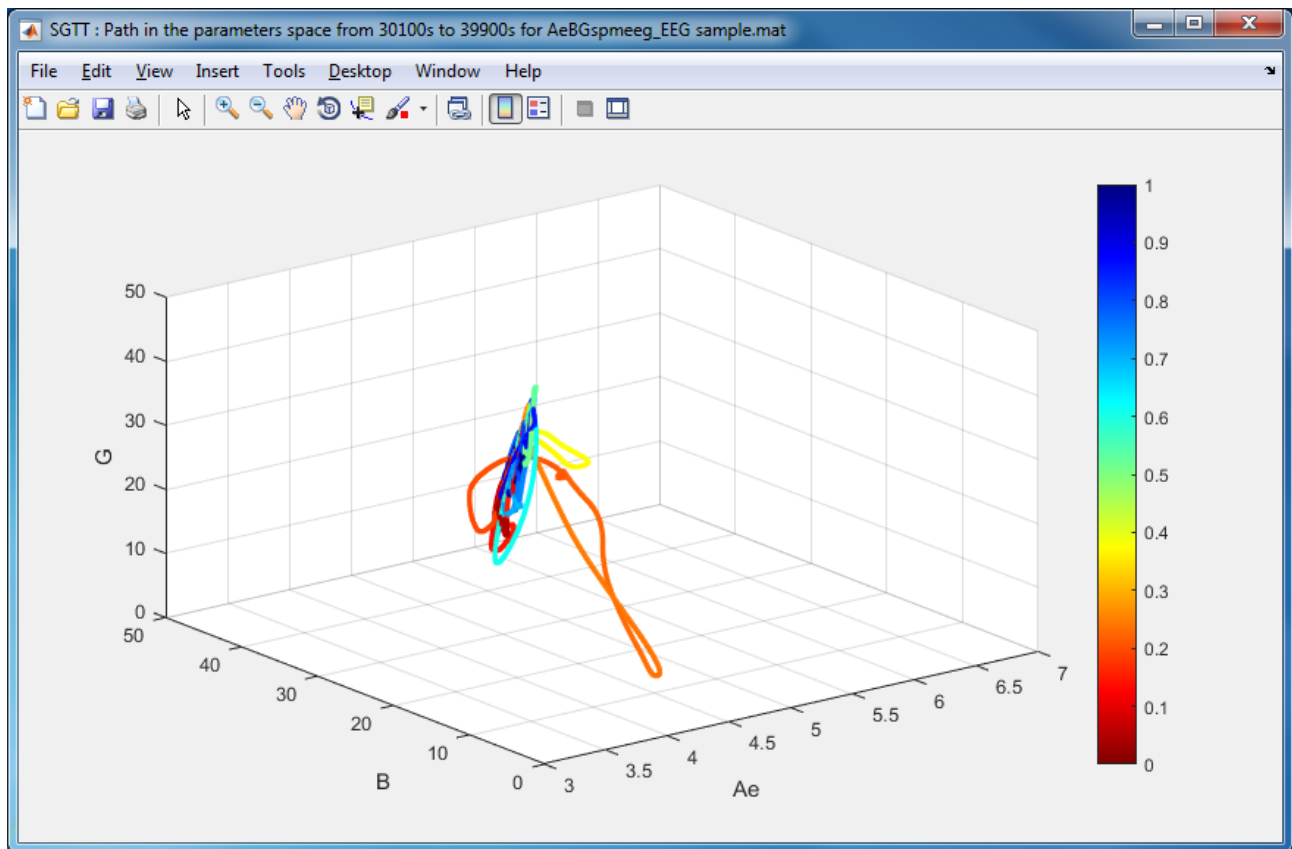


Figure 13. Path in the parameter space in 3D.

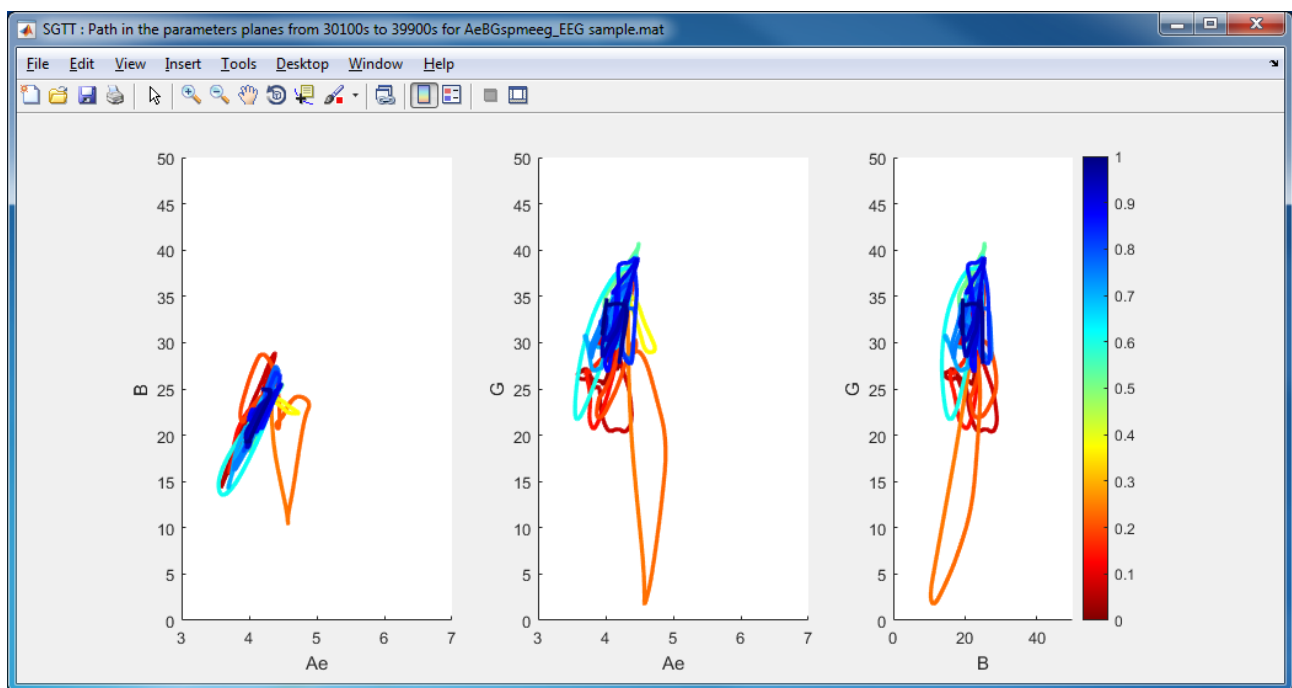


Figure 14. Path in the parameters space, projected in 3 views.

VISUALIZE THE RESULTS

The “EEGAnalyzer” toolbox provides a user-friendly interface for EEG visualization. It reads SPM EEG files and also offers basic EEG filtering options.

After the installation of the “EEGAnalyzer” (version 1) toolbox (please see “SPM AND SGTT INSTALLATION”), it will appear as a toolbox in SPM menu, i.e. (4) in Figure 2. After selecting it, a window appears (Figure 15). Now you can visualize the results obtained from the SGTToolbox.

- Visualization of synaptic gains (Ae, B and G)
 - 1) Click File (1), and select “Open a SPM EEG file Ctrl + o”, the file explorer will be open (By default, it opens the SPM folder). Select the SPM EEG containing the computed synaptic gains. If you do not change the output filename, it should be the converted SPM filename with prefix “AeBG”.
 - 2) In the area (2) in Figure 15, the channels will appear. By selecting them, they will be shown in (4) in Figure 15. Multiple channels can be selected with the help of “ctrl”. Note that each time you click the channels’ names, the display area, i.e. (4) in Figure 15, will be updated. By clicking (3), i.e. the black triangle, in Figure 15, the area (2) will be hidden and offer a larger visualization area (4). Figure 16 shows an example of temporal evolution of synaptic gains. The voltage axis is reversed by default. This can be modified by clicking “Inverse Voltage axe Ctrl+Y” under the “options” tab. Let us note that they are the original values without smoothing.

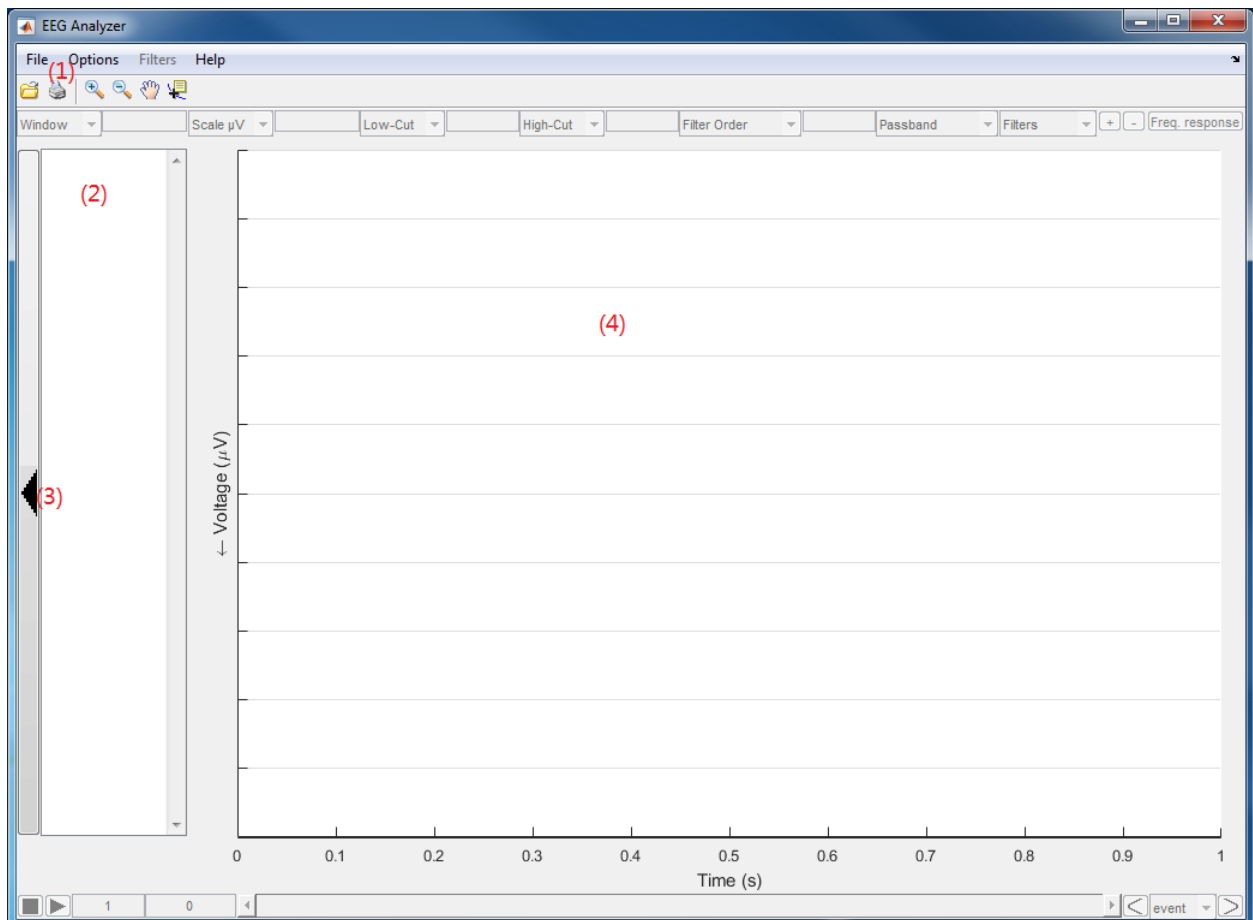


Figure 15. EEGAnalyzer main window

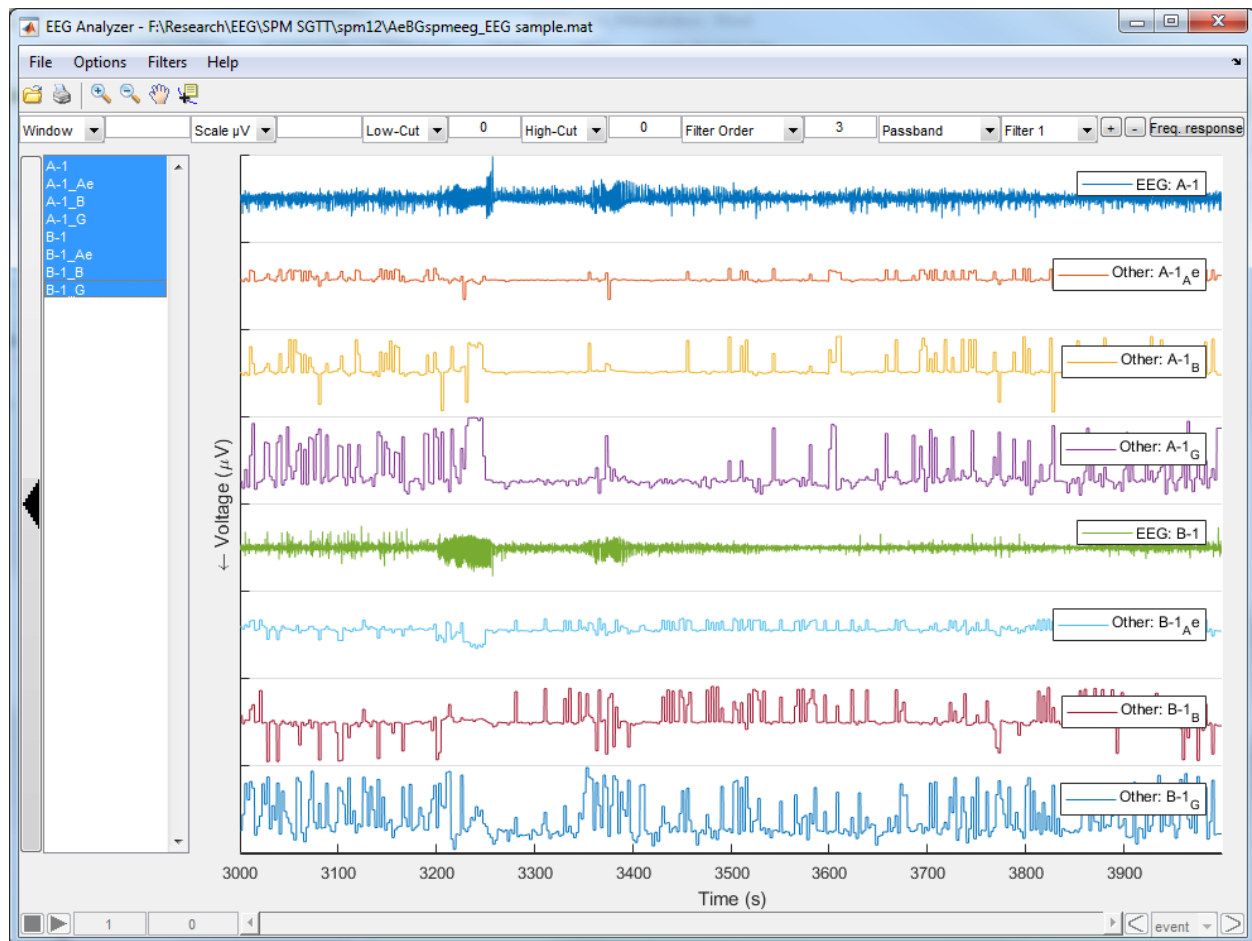


Figure 16. Example of visualization of synaptic gains

- Visualization of Cues
 - 1) Click File (1), and select “Open a SPM EEG file Ctrl + O”, the file explorer will be open (By default, it opens the SPM folder). Select the SPM EEG containing the computed cues. If you do not change the output filename, it should be the converted SPM filename with prefix “CuesAeBG”.
 - 2) In the area (2) in Figure 15, the channels will appear. By selecting them, they will be shown in (4) in Figure 15. Multiple channels can be selected with the help of “ctrl”. Each time you click the channels’ names, the display area, i.e. (4) in Figure 15, will be updated. Figure 17 shows an example of temporal evolution of cues. The file contains the original EEG channel signal (A-1, B-1, etc) and the computed cues (smoothed cues (A-1sR1, A-1sR2 etc.) in the example). The increase of cues may imply (indeed corresponds to in the example) the occurrence of a seizure, as demonstrated in [Fan2018a]. Let us note that the voltage axis is reversed by default. This can be modified by clicking “Inverse Voltage axe Ctrl+Y” under the “options” tab.

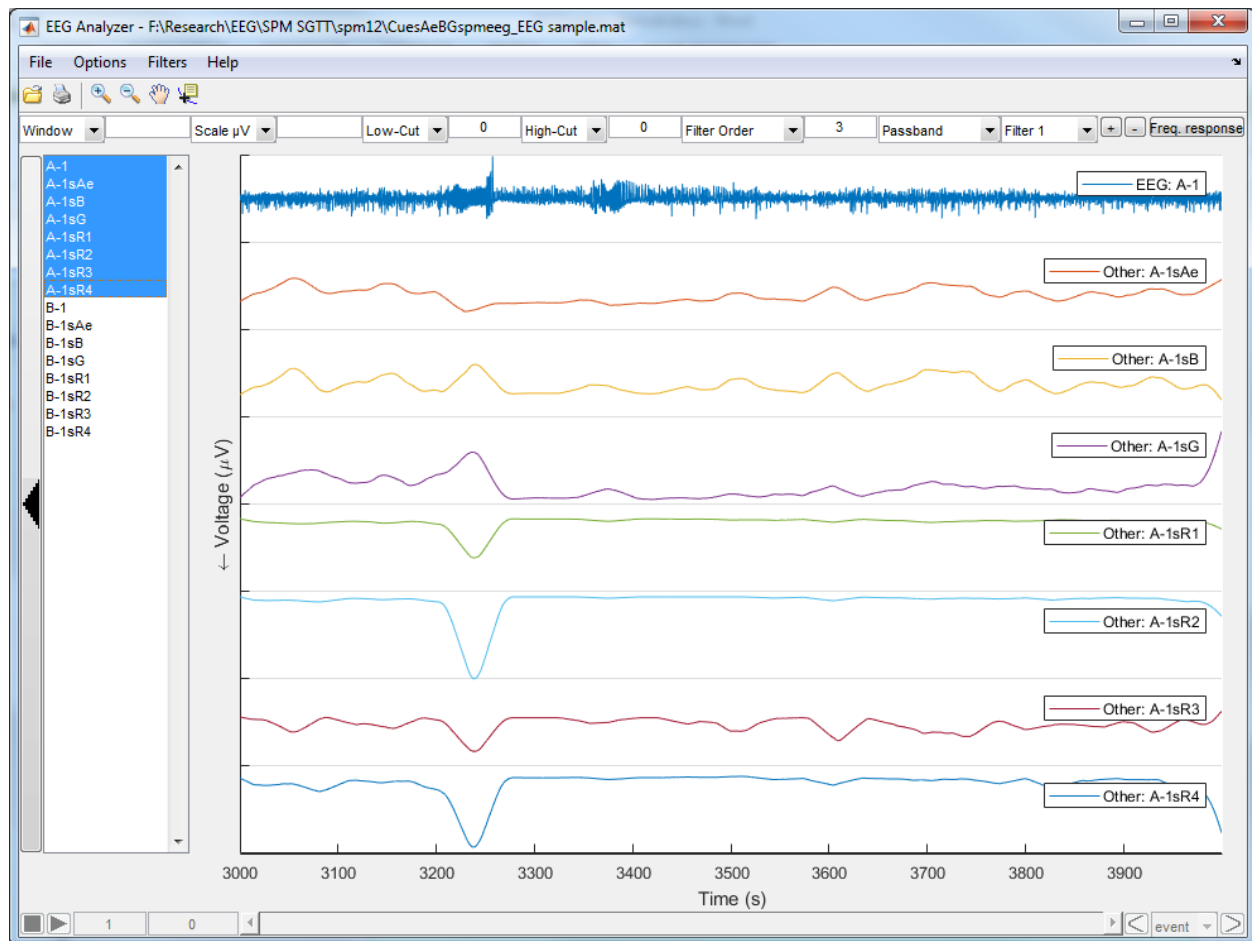


Figure 17. Example of visualization of cues

7 ACKNOWLEDGEMENT

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